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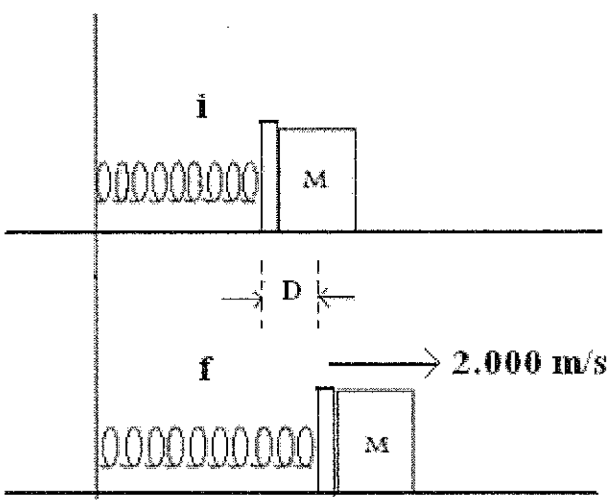
1. (40 POINTS)

At the instant shown, a 2.000-kg block has been pressed against a spring to a compression distance D. The block is released from *rest* from that position and moves right. The spring has force constant k = 10.00 N/m and is attached to a wall. The diagram below shows time sequence shots of the block and compressed spring at rest *initially* (i) and *finally* (f) after the block has moved to the right to where the spring is un-deformed (not compressed or stretched). In the *final* position shown below the block has speed 2.000 m/s as it moves right. The *coefficient of kinetic friction* between the horizontal ground and bottom of the block is μ = 0.200.

(a) (24 points) What is D (in m)?.

(b) (10 points) What is the work done by friction (in Joules) during this motion? Is this work positive or negative? Explain.

(c) (6 points) The block *loses contact* with the *un-deformed* spring at the final (f) position shown below. Thus, the block continues motion to the right without being connected to the spring. How far from this position will the block travel to the right before finally coming to *rest* ?



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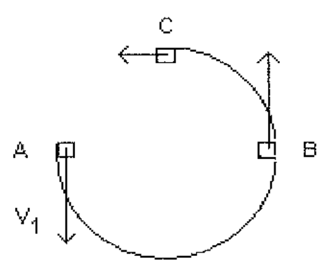
2. (40 POINTS) A block of mass m = 1.000 kg slides counter-clockwise along the inside of a *3-quarter circular* track of radius R = 20.0 m. The block starts out moving vertically downward at point A at the end of a horizontal diameter with initial speed $V_1 = 40.0$ m/s and exits at point C at the top. No friction.

(a) (6) What is the magnitude N of the normal force of the track on the block when it reaches point B at the *other* end of the horizontal diameter ? What is the direction of the normal force at this point?
(b) (4) At point B what is the *magnitude* $|a_t|$ and *direction* of the *tangential* acceleration ?
(c) (23 points) What is the magnitude N of the normal force of the track on the block just before it reaches point C at the top ? What is the direction of the normal force at this point?
(d) (7 points) At point C, the mass exits the track and undergoes projectile motion (with no air resistance) until it hits the ground at the *same vertical level* as the *bottom* of track. Use *conservation of energy* to compute the *speed* of the mass just before it hits the ground.



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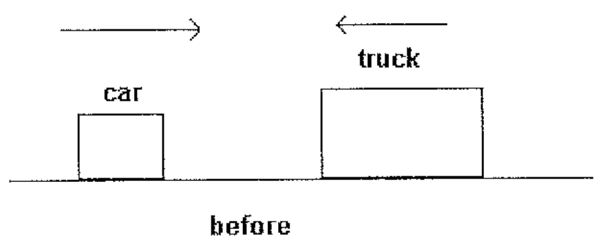
3. (38) In a simulated experiment, a subcompact car with a mass 950.00 kg traveling to the *right* with speed 15.00 m/s collides with a truck of mass 1900.00 kg traveling to the *left* with speed 10.00 m/s. See schematic below of the situation before the collision; no person is hurt in the simulation. The two cars *stick together* as a result of the collision and just after colliding they move together with a common speed $|V_f|$.

(a) (18) What is the speed $|V_f|$?

(b) (10) What is the direction of motion of the *stuck cars* immediately after the collision, left or right? (circle one)

(c) (10) Assume the kinetic energy of the system is lost to heat. How much heat energy is created during the collision?



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4. (12 points) A wheel is rotating about an axis that is in the z-direction. The angular velocity is $\omega_0 = -6.00$ rad/s at t = 0 and *increases linearly* with time at constant angular acceleration α. At t = 7.00 seconds, the angular velocity is $\omega_7 = +8.00$ rad/s. We have taken counter-clockwise rotation to have *positive* angular velocity.

(a) (2 points) Is the angular acceleration α positive or negative?
(b) (4 points) Through what angle (in rads) does the wheel rotate in the time interval between 0 and 7.00 seconds?
(c) (4 points) At what time t does the wheel momentarily come to *rest?*
(d) (2 points) During what time interval is the speed of the wheel increasing? Decreasing?

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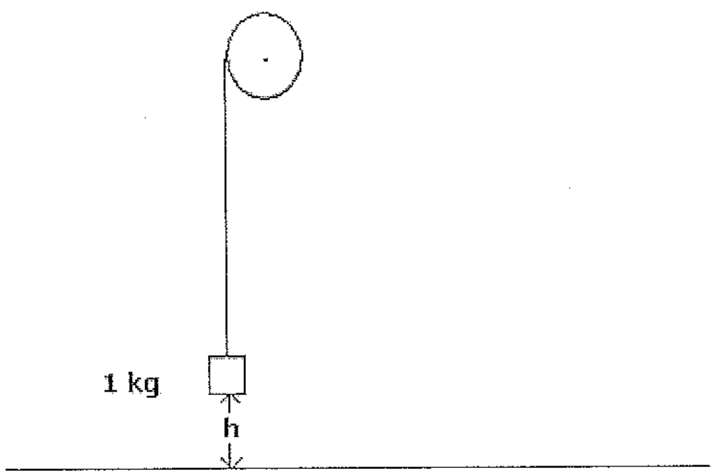
5. EXTRA CREDIT. (11 POINTS) A 1.000-kg block hangs vertically at the end of a string wrapped around a pulley of radius R = 0.250 m and mass M = 2.000-kg shaped in the form of a solid cylinder. Thus, the pulley has $I = \frac{1}{2}MR^2$ about the axis of rotation through the center. The vertically hanging block and pulley are shown at the start of the motion when they are released from *rest.* The block is released from a height h = 1.000 m above the ground.

What is the linear speed v of the block *just before* it hits the ground?



(1)

$\frac{1}{2}KD^2 = \frac{1}{2}mv^2 + f_k \cdot D$

$\frac{1}{2}KD^2 = \frac{1}{2}mv^2 + \mu_k mgD$

$\frac{1}{2}KD^2 - \mu_k mgD - \frac{1}{2}mv^2 = 0$

$\frac{1}{2}(10)D^2 - (0.2)(2)(9.8)D - \frac{1}{2}(2)(2)^2 = 0$

$5D^2 - 3.92D - 4 = 0$

$D = \frac{3.92 \pm \sqrt{3.92^2 + 4(5)(4)}}{10}$

$= \frac{3.92 \pm \sqrt{15.36 + 80}}{10}$

$= \frac{3.92 \pm \sqrt{95.36}}{10}$

$= 1.36\ (m)$

(b) $-f_k \cdot D$

$= -(0.2)(2)(9.8)(1.36)$

$= -5.36\ J$

(c) $\frac{1}{2}m(2)^2 = \mu_k mgd$

$\frac{1}{2}(2)(2)^2 = (0.2)(2)(9.8)d$

$d = \frac{4}{(0.2)(2)(9.8)}$

$= 1.02\ (m)$

(2) (a) $N = \frac{mv^2}{R}$

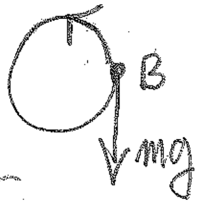
$N = \frac{(1)(40)^2}{20}$

$= \frac{1600}{20} = 80\ (N)$

(2)

(b) $m|a_t| = m \cdot g$

$|a_t| = g$



a_t is down.

(c)

$\frac{1}{2} m (40)^2 + mgR$

$= \frac{1}{2} m V_C^2 + mg(2R)$

→ $\frac{1}{2} m (1600) - mgR = \frac{1}{2} m V_C^2$

$\frac{V_c^2}{2} = 800 - (9.8)(20)$

$= 800 - 196$

$= 604$

$V_c = 34.64 \frac{m}{s}$

$\frac{mV_c^2}{R} = N + mg$

$N = \frac{mV_c^2}{R} - mg$

$N = (1)\left(\frac{34.64^2}{40} - 9.8\right)$

$N = 30.189 - 9.8$

$N = 20.4 \,(N)$

(d) final kinetic energy at the ground.

$\frac{1}{2} m V_c^2 + mgh = \frac{1}{2} m V_f^2$

$\frac{1}{2}(1)(1208) + (1)(9.8)(2R)$

$= \frac{1}{2}(1) V_f^2$

$604 + (1)(9.8)(40) = \frac{V_f^2}{2}$

$V_f = 44.63 \frac{m}{s}$

Notes:

$34.64 \cdot t = \Delta X$

and $\frac{1}{2} g t^2 = 2R = 40$

$t = \sqrt{\frac{80}{9.8}} = 2.86 \,(s)$

$\Delta X = (34.64)(2.86)$

$\Delta X = 99.3 \,(m) > R = 20 \,(m)$

(3) (a.)

$(950)(15) - (1900)(10)$

$= (2850)\, V_f$

$14{,}250 - 19000 = (2850) V_f$

$V_f = \dfrac{-4750}{2850}$

$= -1.67 \frac{m}{s}$

(b.) ←

(c) $\frac{1}{2}(2850)(1.67)^2$

$= 3974.33\ J$

$= KE_f$

$KE_i = \frac{1}{2}(950)(15)^2$

$+ \frac{1}{2}(1900)(10)^2$

$= \frac{1}{2}[213750 + 190000]$

$= 201875\ J$

(c)

$|\Delta KE| = \text{Heat}$

$= 197917\ J$

NEARLY ALL LOST TO HEAT!

(4.)

(a.) $\alpha > 0$

↺ speeds up CCW between 3 and 7 seconds

(b.)

$\Delta\theta = \dfrac{(\omega_0 + \omega_7)}{2}(7s)$

$= \dfrac{(-6 + 8)}{2}(7s)$

$= \left(\frac{2}{2}\right)(7s) = 7\ \text{RADIANS}$

NOTE $\Delta\theta = (7\ \text{RAD}) \times \dfrac{1\ \text{REV}}{2\pi\ \text{RAD}}$

$= 1.114\ \text{REV}$

(c.)

$\omega = 0 = \omega_0 + \alpha t$

$0 = -6 + \alpha t$

$\alpha = \dfrac{\Delta\omega}{\Delta t} = \dfrac{8-(-6)}{7} = 2\ \frac{\text{RAD}}{s^2}$

$0 = -6 + 2 \cdot t \rightarrow t = 3\,(s)$

~~(4)~~ (4)

- angular speed increases between 3 and 7 seconds.
- angular speed decreases between 0 and 3 seconds.

(5) See ZB solutions